A laser cavity for polarised positron production ?

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(With help from J. Urakawa and others)

Introduction

Up to now two ideas to produce polarised positrons

1. helical undulator in the high energy beam
2. Compton scattering of a low energy electron beam with a CO_2 laser

Both schemes produce polarised photons which are converted into polarised positrons in a thin target

Advantage undulator

- seems technically easier
- small power cost

Advantage Compton scattering

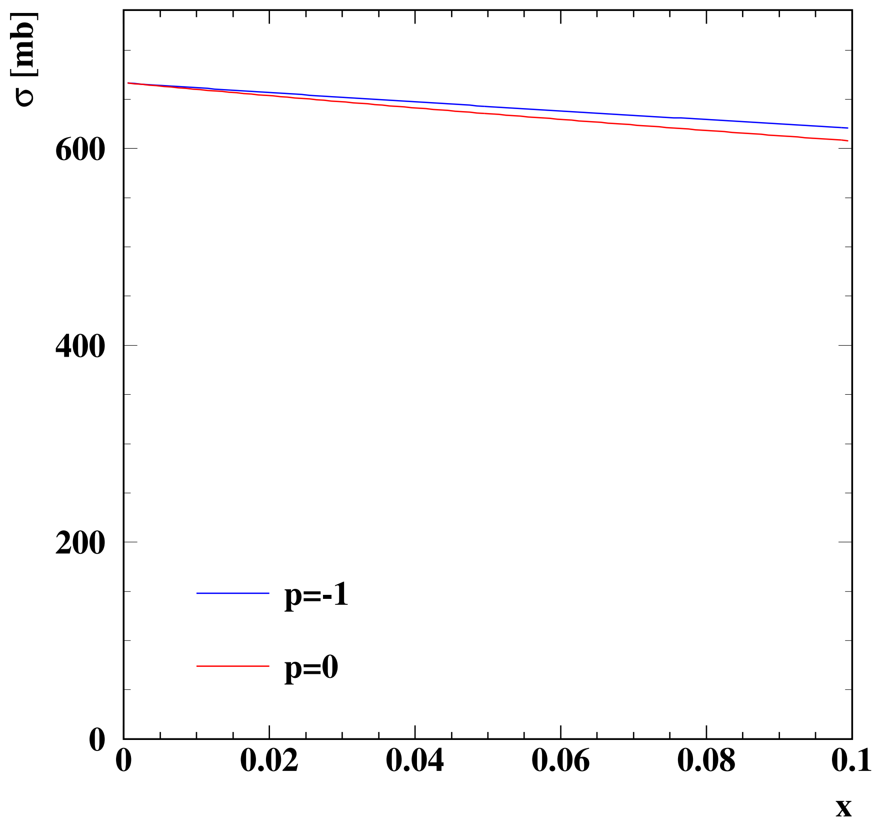
- independent of electron arm
- no additional energy spread

Basics Compton scattering

Basic variable (scaled squared $e\gamma$ cms energy)

$$x = \frac{4E_0\omega_0}{m^2c^4}\cos^2\frac{\alpha}{2} \simeq 0.019\left[\frac{E_0}{\mathrm{GeV}}\right]\left[\frac{\mu m}{\lambda}\right]$$

Maximum scattered photon energy $E_\gamma < x/(x+1)E_b$



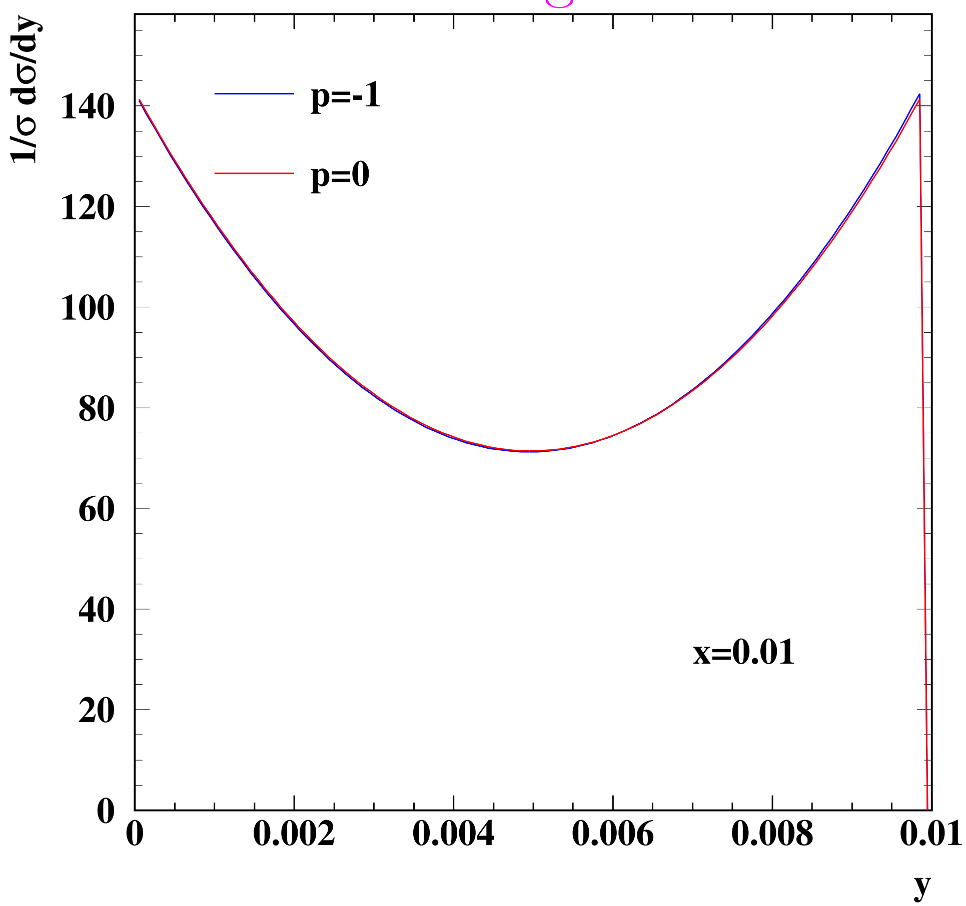
Relevant range for positron polarisation:

$$x = \mathcal{O}(0.01)$$

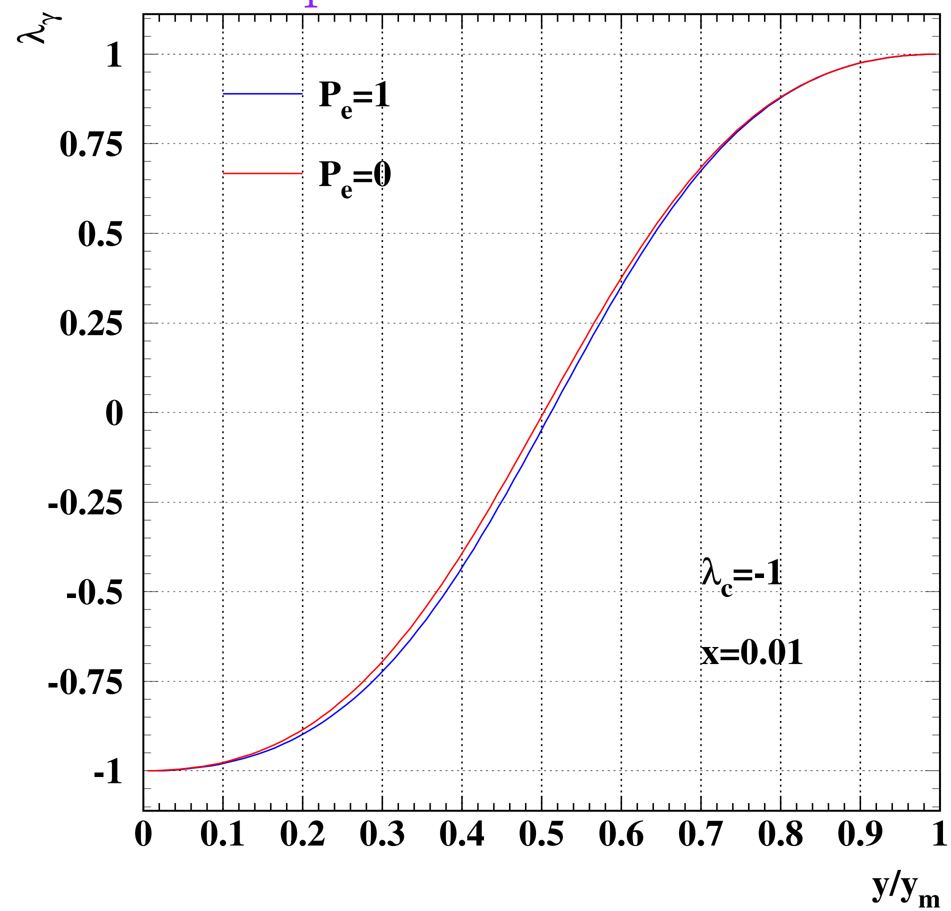
Cross section depends on product $\mathcal{P}_e\lambda_\gamma$

In the relevant range little dependence on x and polarisation

Photon energy peaked at high and low energies



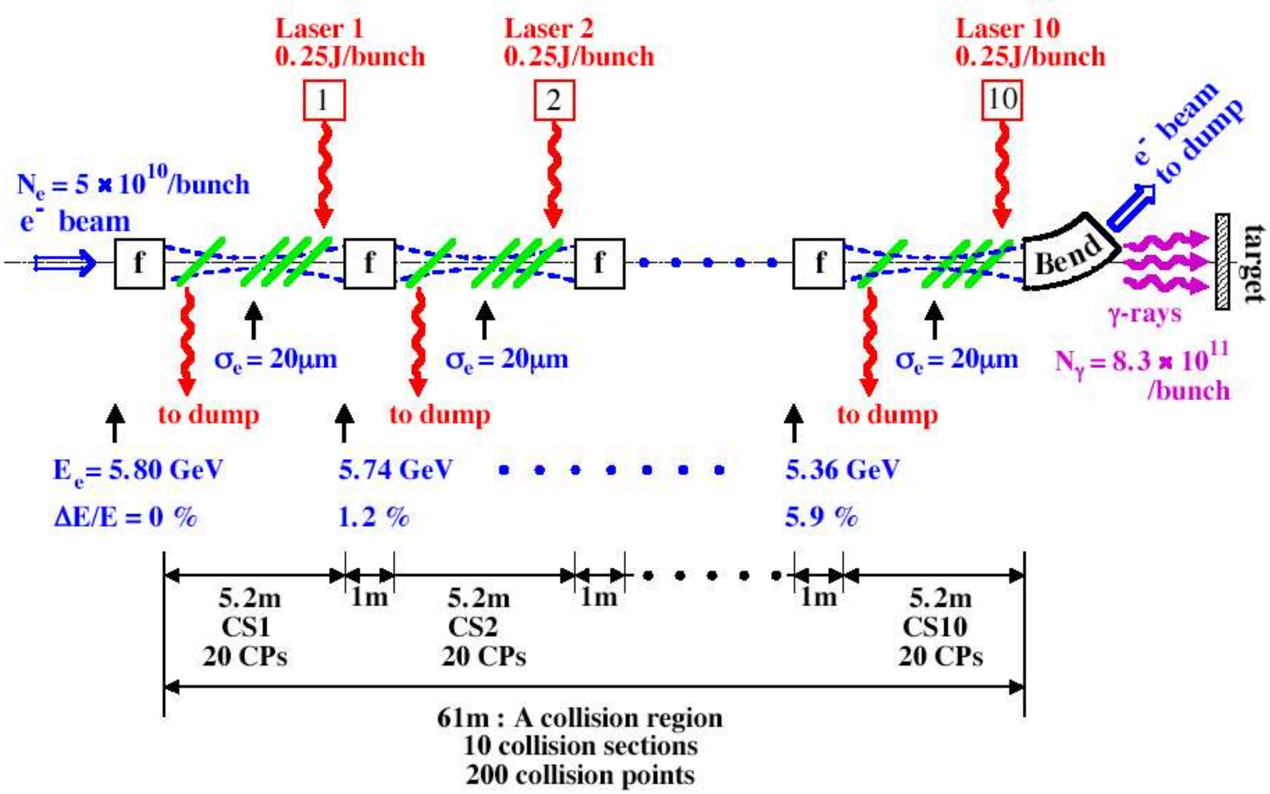
Photon polarisation large for polarised laser



- Selection of high photon energies results in high polarisation
- This polarisation is transfered to the positron in the pair-production if high energy positrons are selected

The Japanese concept

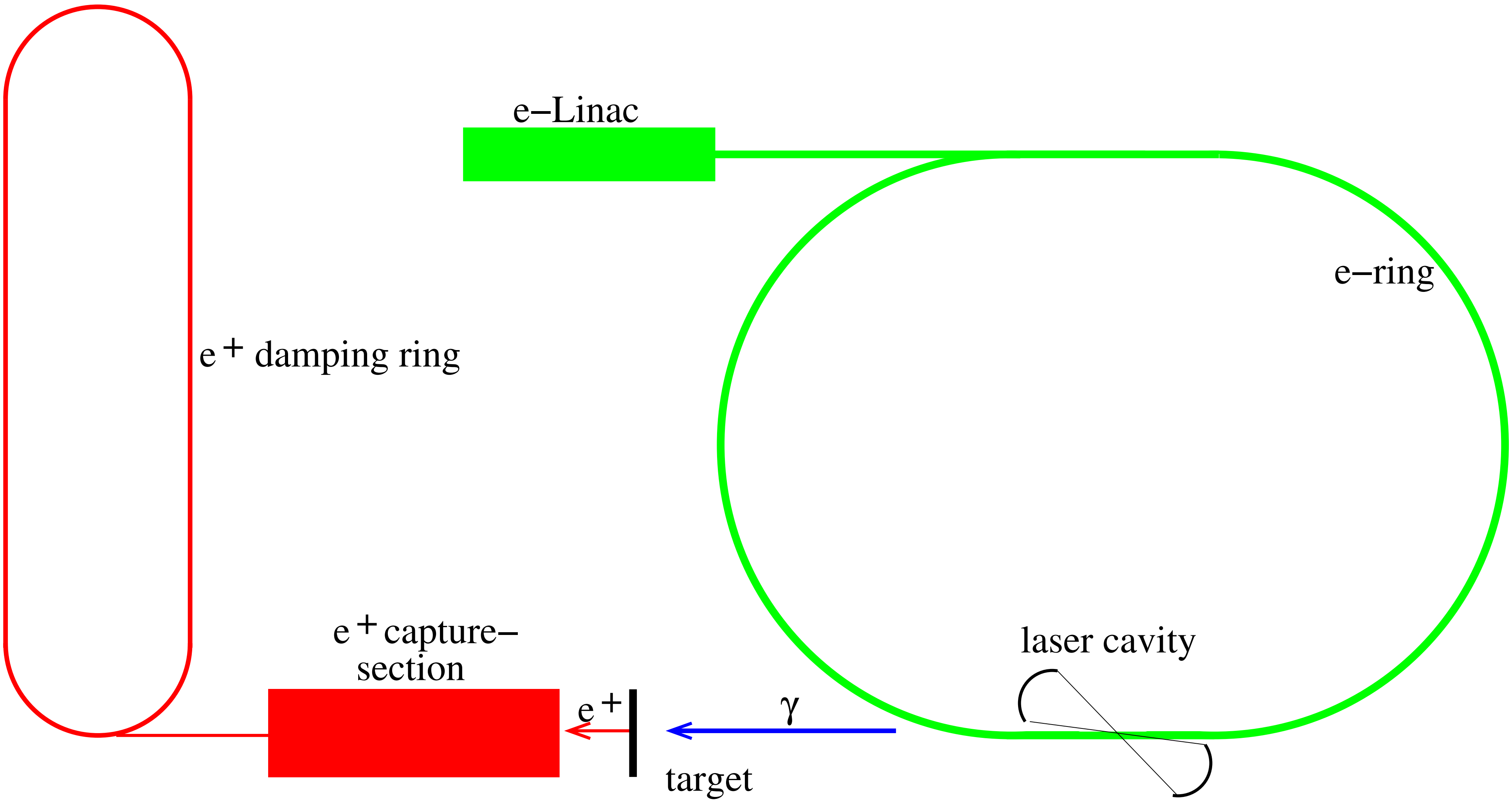
- electron beam with $E_b = 5.8\,\mathrm{GeV}$ from a linac
- CO_2 laser ($\lambda = 10.6\mu\mathrm{m}$) ➡ $x = 0.01$, $E_\gamma < 50\,\mathrm{MeV}$
- need about 70 γs/high energy positron
- realised with 10 lasers and 20 conversion points each



Improved Compton concept?

- In the damping ring the e^+ are stored with a much smaller distance than the ILC bunch spacing
  (Assume 3 ns as proposed by KEK study)
  $\Rightarrow$ can use this bunch spacing for positron production
- Propose to store the electrons in a storage ring with this bunch spacing
- Collide them in one (or few) points with a laser cavity
  - Use Nd:Yag or similar laser ($\lambda = 1.06\mu$m)
  - 10 times smaller luminosity than CO_2 laser for same parameters
  - however much easier to build a cavity and smaller spotsizes possible
  - at KEK a prototype with 5μm spotsize and 3° crossing angle will be built (J. Urakawa)

The oncept for positron generation



A possible storage ring (J. Urakawa)

1.38GeV Electron Storage Ring with full coupling operation:

- emittance $\epsilon = 0.3 \cdot 10^{-9}$ m
- bunch length 3 mm,
- 714 MHz RF acceleration
- two 50 m straight line for γ-generation and beam injection/extraction
- $25 \times 10\mu\text{m}^2$ beam sizes at IPs
- 200 bunches/train $\times$ 2 trains = 400 bunches/ring
- bunch spacing = 2.8 ns, train gap = 60 ns
- total: $199 \times 2.8\,\text{ns} \times 2 + 120\,\text{ns} = 1234.4\,\text{ns}$ $\Rightarrow$ circumference $\approx$ 370 m
- Bunch charge 3.0 nC, Total circulating charge=1200 nC, Current 1.78 A.

Laser cavity:

- pulse energy 0.1 J
- waist $10 \times 10\mu\text{m}^2$
- pulse length 0.9 mm
- crossing angle 5°

- Maximum energy loss of e^-: 2.5%, should be ok
- Electron conversion probability $\sim 0.2\%$/crossing
- Time between trains $\sim 200\,\mathrm{ms}$
  $\Rightarrow$ assume I can collect positrons for $\sim 100\,\mathrm{ms}$
- Generate $1.3 \cdot 10^{15}$ photons in this time
- With an efficiency $\gamma \to$ captured e^+ of 1/70 (Omori et al.) need $3.9 \cdot 10^{15}$ photons per ILC train
- This requires 3 laser cavities
- Some further optimisation still possible

Problems with this scheme

How long can we keep the scattered electrons in the ring?

- The bandwidth allows for one maximum or two "average" scatters
- How many turns do we need until the electron energy is recovered?
- Can we use dispersion effects to protect the low energy electrons?
- We need a low emittance gun to fill the electron storage ring

Can we fill the positron damping ring in this mode?

- The positron emittance at the damping ring entrance is very large
- There might not be enough phase space available to fill the positrons on top of the existing bunch
- Can we use some pre-cooling?

What about radiation damage on mirrors?

- Radiation on mirror $0.05\,\mathrm{J/cm^2}$ per pulse and per Joule pulse energy for mirror distance of $1\,\mathrm{m}$ from IP
- For a single pulse this is far below the critical value of $2.5\,\mathrm{J/cm^2}$ for $2\,\mathrm{ps}$ laser pulses
- However I don't know about data for high repetition rates

Conclusions

- The ILC time structure seems well suited for a polarised positron source using Compton scattering and a laser cavity
- However some important problems still need to be solved
- We need the help of accelerator physicists to progress